

Doppler ultrasound in obstetrics

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Abstract

Doppler ultrasound is used to monitor high-risk pregnancies and time delivery appropriately. Pregnancies with high resistance in the uterine arteries (UtA) are at risk of pre-eclampsia and fetal growth restriction and need close monitoring. Resistance within the umbilical arteries (UmA) reflects the resistance to blood flow within the placenta. In a poorly functioning placenta, resistance will gradually increase and umbilical arterial flow will eventually become reversed at the end of diastole. A chronically hypoxic fetus will dilate its cerebral arteries to divert blood to the brain. This will be demonstrated by a falling resistance in the middle cerebral arteries (MCA). This compensatory mechanism can be monitored by measuring the resistance within these vessels. The ductus venosus (DV) Doppler can be used to monitor fetuses with an abnormal UmA doppler in whom delivery is not yet appropriate. At extreme pre-term gestation delivery should be planned dependent on changes in the DV blood flow.

Keywords cerebro-placental ratio; ductus venosus doppler; extreme prematurity; high-risk pregnancy; middle cerebral artery doppler; preterm delivery; umbilical artery doppler; uterine artery doppler

Introduction

Umbilical artery (UmA) Doppler measurement is something that all obstetricians should be familiar with, but the measurement of this, in conjunction with middle-cerebral artery (MCA), ductus venosus (DV) and uterine artery (UtA) Dopplers may, at times, seem like the realm of a subspecialist only. It is important that all obstetricians can interpret these Doppler readings so that high risk pregnancies can be monitored and managed optimally.

Perinatal morbidity and mortality in pregnancies complicated by fetal growth restriction is related to the extent of this problem, and the gestational age at delivery. When a fetus is growth restricted because of placental pathology, there will be an increased resistance to blood flow through the placenta. The fetus responds by redistributing blood flow to the heart and brain. Fetal MCA and DV Dopplers enable assessment of these compensatory changes.

In order to minimize perinatal mortality and morbidity, delivery may need to occur before 37 weeks' gestation. Fetal

Dopplers are helpful in timing delivery and limiting iatrogenic prematurity, particularly at the extremes of viability.

A review of data from the Trent region published in the BMJ showed that for babies whose birthweight was on the 10th centile survival increased from 15% at 24 weeks' gestation to 70% at 27 weeks and to 93% at 32 weeks.

The national multicentre trial, EPICure2, concluded that the chance of survival without disability improved from 28% if born at 24 weeks to 61% if the pregnancy could be extended to 26 weeks. Extending the gestation at which delivery occurs carries clear potential benefits, provided intervention is not left too late.

This review will focus on the assessment of fetal wellbeing with Doppler ultrasound. A case discussion will be used to demonstrate this, and illustrate how these measurements can be used to help plan the timing of delivery.

Case summary

A dichorionic diamniotic twin pregnancy with significant discordance in fetal size provides a good example of how Doppler ultrasound can be utilized to time delivery. The need to reduce the risk of stillbirth in the smaller twin, whilst also limiting iatrogenic extreme prematurity in the healthy twin, illustrates well the value of Doppler assessment.

A 29 year nulliparous woman with rheumatoid arthritis, controlled with Sulphasalazine, is under the care of the maternal medicine clinic. She is first seen in this clinic at 14 weeks' gestation where she learns that she is carrying dichorionic diamniotic twins, conceived spontaneously. The crown-rump lengths are discordant but the nuchal translucency measurements are 'normal'. Because of this early-onset fetal size discordance she is scanned regularly in the fetal medicine department from 16 weeks' gestation. The possible causes of this size discrepancy are discussed with the woman and her partner, including selective fetal growth restriction secondary to impaired placentation, and structural or chromosomal abnormality in the smaller twin. Both fetuses continue to grow along their respective centiles and no obvious structural abnormalities are found on detailed scanning, in either twin. They opt for non-invasive prenatal testing which gives a low chance for trisomy 13, 18 and 21.

From 24 weeks' gestation UmA, MCA and DV Dopplers are used to monitor the wellbeing of the twins, with particular focus on the smaller one. At 25 weeks' gestation the UmA pulsatility index (PI) is found to be raised, although the end diastolic flow (EDF) remains positive. The DV is normal but the MCA is already showing some re-distribution of blood to the brain.

By 26 weeks' gestation the EDF in the UmA has become intermittently absent, and by 27 weeks it is persistently absent. At this point the woman is admitted to hospital for very close in-patient surveillance.

At 28 weeks' gestation the PI within the DV is found to be elevated (although the a-wave is still present). Twice daily computerized cardiotocogram (cCTG) recordings are being performed, as well as multi-Doppler assessment two to three times per week.

By 29 weeks' gestation the EDF within the UmA has reversed and the MCA Doppler is showing profound re-distribution of blood to the brain. The DV PI remains elevated but with a normal

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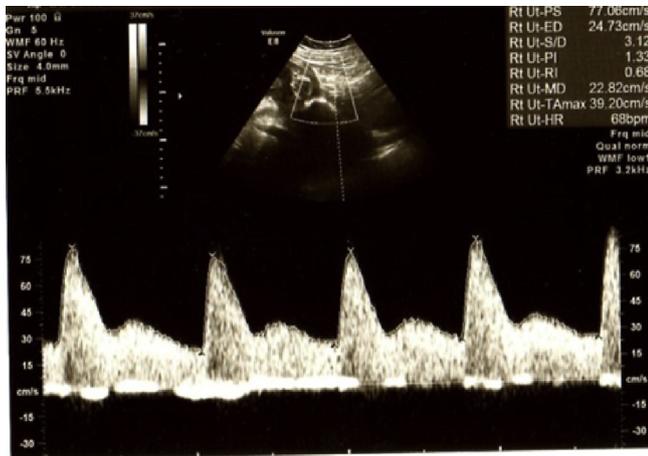


Figure 1 A 'notched' UtA waveform.

a-wave. By 30 weeks and 6 days the DV a-wave is lost (absent) and immediate delivery is deemed necessary.

The babies are born that day in good condition via lower-segment caesarean section weighing 1900g and 620 g respectively. Both require prolonged neonatal care but are well at their first birthday and appear not thought to have suffered any obvious sequelae of their prematurity, or fetal growth restriction.

Uterine artery Doppler

Uteroplacental blood flow is an important determinant of fetal growth and development. Maternal uterine spiral artery remodelling leads to a low resistance uteroplacental circulation. This is reflected by increases in blood flow and a reduction in resistance in the uterine arteries (UtA) as pregnancy progresses.

The uterine artery waveform is visualized by sliding the probe off the uterus into the women's iliac fossae. The uterine artery is then found medial to the bifurcation of the common iliac artery. The wave-forms should be reported for both the right and left uterine arteries. Because of the lie of the uterus the resistance will usually be higher in the right uterine artery. Pre-eclampsia and intrauterine growth restriction are both associated with abnormal placentation which results in inadequate utero-placental blood flow. In pregnancies affected by preeclampsia or fetal growth restriction there is increased resistance in the UtA blood flow and persistence of the end-diastolic notch beyond 24 weeks' gestation (Figure 1). Therefore, UtA Dopplers can be used to help predict pre-eclampsia or fetal growth restriction.

If UtA Dopplers are normal (Figure 2), further consideration needs to be given to other causes of fetal growth restriction, such as structural or chromosomal abnormalities, genetic syndromes, or infections, such as cytomegalovirus.

The blood flow within the UtA can also be used to triage high-risk pregnancies. Resistance to flow should normally fall with advancing gestation. The presence of a low resistance pattern is associated with a reduced chance of pregnancy complication (<1% chance of developing pre-eclampsia, PET, or fetal growth restriction, FGR).

The role of UtA Doppler assessment in high risk pregnancies is clear; however its place as a screening tool in low risk pregnancy remains controversial. A Cochrane review of data from

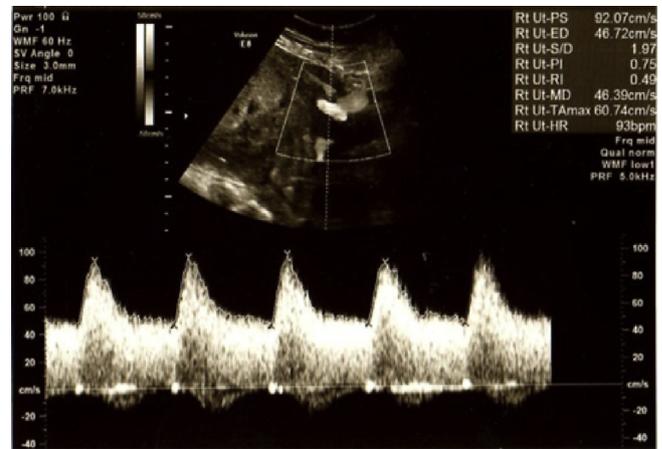


Figure 2 A normal UtA waveform.

nearly 5000 women published by Stampalija et al. in 2010 concluded there was no benefit when UtA Doppler assessment was made in the second trimester in women at low risk of hypertensive disease.

The RCOG Green-top Guideline 'The Investigation and Management of the Small-for-Gestational-age Fetus' suggests that all women with three or more 'minor' risk factors for having a small baby should be offered assessment of UtA blood flow at 20–24 weeks' gestation (Figure 3). If the UtA Doppler is abnormal then there should be serial assessment of fetal growth and UmA Doppler flow from 26 weeks' gestation. If it is normal then assessment of size and UmA blood flow can be left until the 3rd trimester.

If fetal growth restriction is diagnosed in a singleton pregnancy, the finding of a 'notched' UtA Doppler wave form is supportive of a diagnosis of utero-placental insufficiency. This, in combination with normal nuchal translucency measurement, normal anatomy and a negative viral screen helps to guide counselling and the optimal timing for delivery. The use of UtA Dopplers in twin pregnancy is not well established.

Umbilical artery Doppler

The presence or absence of the end-diastolic flow (EDF) within the UmA will routinely be reported on an obstetric scan but having an understanding of what this actually means and the preceding changes in the blood flow will help guide when delivery is truly necessary.

The resistance within the umbilical arteries (recorded as the Pulsatility Index, PI) reflects the resistance to flow within the placenta. In a normally functioning placenta the resistance to blood flow should steadily decrease throughout the pregnancy in response to ongoing development of the placental bed.

The resistance to flow within the vessels in the placenta is normally low enough that even in diastole there is substantial forward blood flow (Figure 4). In an abnormally functioning, or insufficient placenta, the resistance will remain high. This will be reflected in a PI above the expected range for gestation. Once the resistance reaches a critical level, blood flow during diastole will be impeded (Figure 5), termed 'absent end-diastolic flow (EDF)'. Eventually blood flow will be reversed back towards the fetus

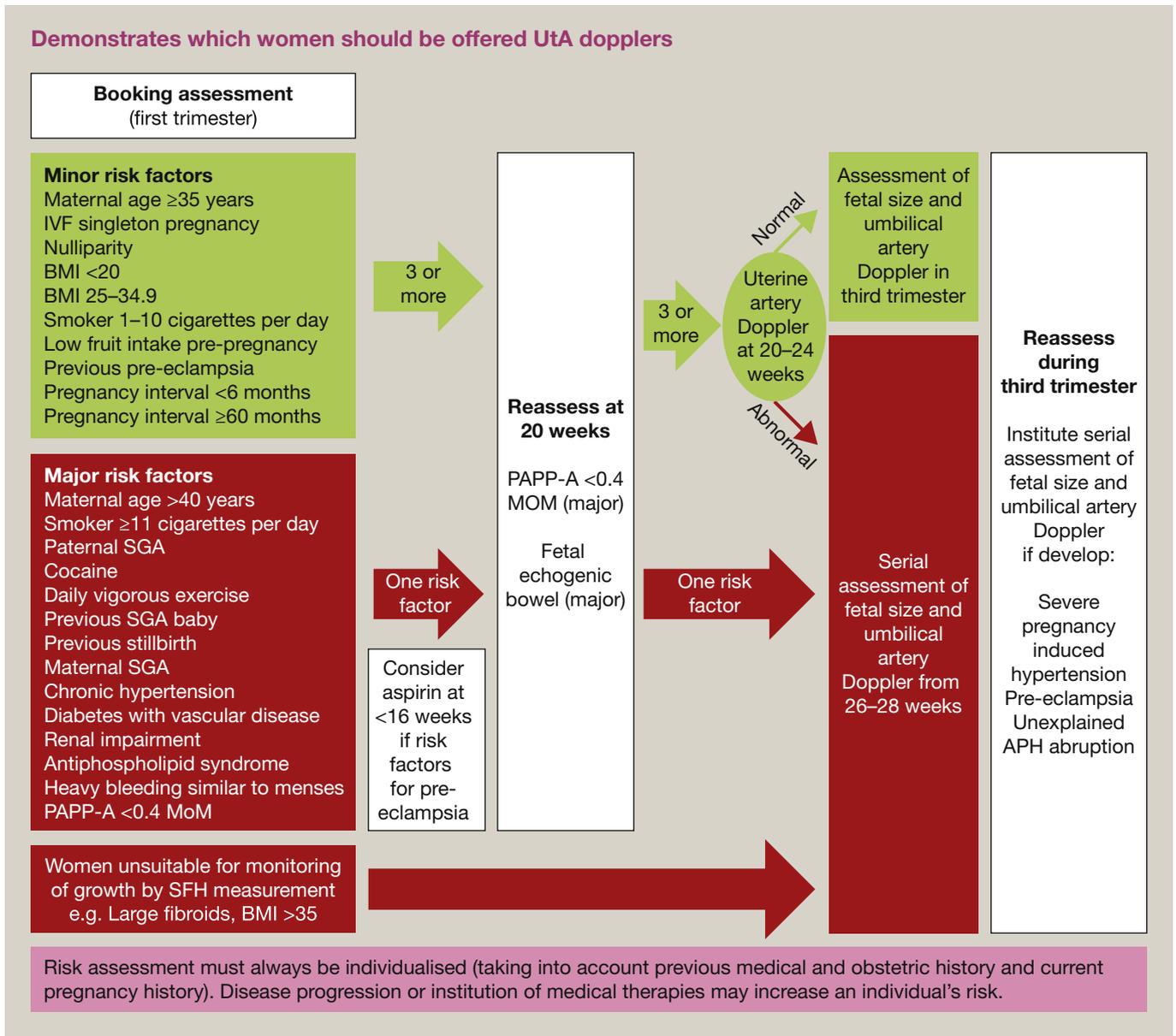


Figure 3

during fetal diastole (Figure 6), termed 'reversed EDF'. A low UmA PI is of no significance.

The natural progression seen in a fetus that is deteriorating would be a steady increase in the UmA PI followed by an intermittently and then persistently absent EDF and, finally, reversed EDF. Resistance high enough to have caused a reversal in blood flow during diastole suggests that a significant proportion of the trophoblastic villi have been obliterated. This should necessitate consideration of immediate delivery. However, if this would expose the fetus to the risks of extreme prematurity then concurrent monitoring of the DV and MCA values may be helpful. The time between reversal of end diastolic velocities, a critical fetal hypoxia, acidaemia and death is varied, but may be very limited and discussion with a Fetal Medicine Unit that can conduct assessment of the DV and MCA blood flows should be considered before this critical stage is reached.

A Cochrane review by Alfirevic et al. published in 2015 looked at data from over 14000 women and concluded that the routine assessment of UmA Dopplers in low-risk or unselected populations does not improve outcomes for mother or baby.

In high-risk populations monitoring the UmA blood flow and correctly interpreting the findings is thought to reduce perinatal morbidity and mortality. The RCOG recommends using the UmA doppler ultrasound as the primary surveillance tool in small fetuses. All women with a single major risk factor for a small baby should be offered serial assessment of fetal growth and UmA blood flow from 26 weeks' gestation (see Figure 3). Whilst the UmA PI is normal the readings should be repeated fortnightly. If the UmA PI becomes raised, then more extensive fetal assessment is needed at least weekly, increasing further even to daily assessments if the end diastolic flow is absent or reversed, until delivery is appropriate. Even if DV and MCA Doppler

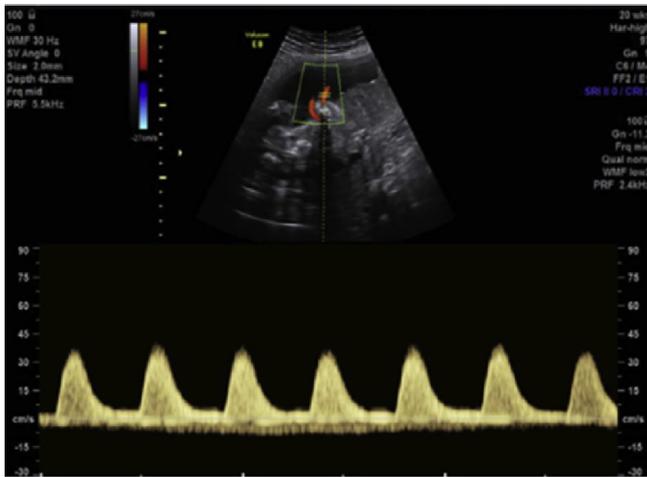


Figure 4 A normal waveform in UmA.

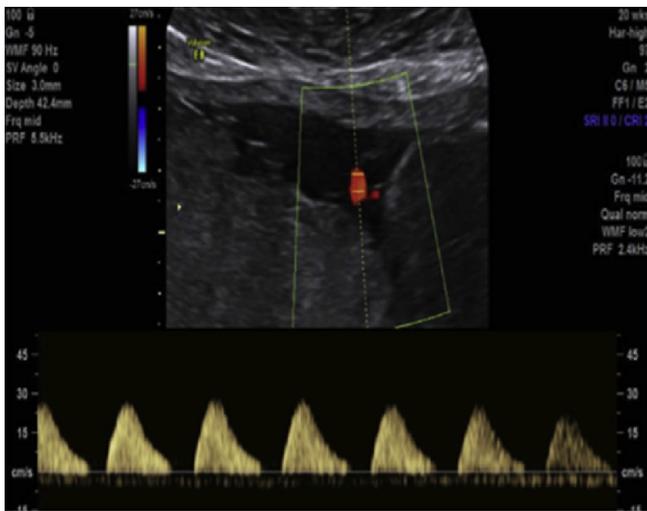


Figure 5 Absent EDF in the UmA.

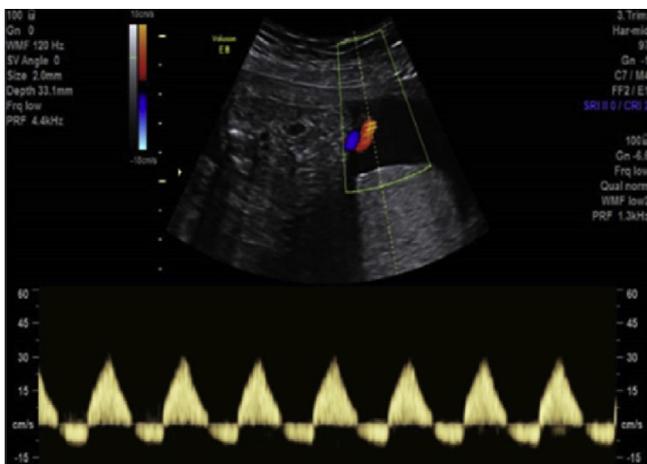


Figure 6 Reversed EDF in the UmA.

measurements are normal, absent or reversed UmA Doppler recordings should prompt consideration of delivery by 32 weeks' gestation (with steroid cover). Although UmA Doppler values

may sometimes be elevated in late onset growth restriction (after 32 weeks' gestation), this is less often the case if they have been normal prior to this time. A pregnancy with forward end-diastolic flow but raised UmA Doppler PI (above the 95th centile) should not continue beyond 37 weeks' gestation and a normal UmA Doppler PI should not be considered unduly reassuring in a fetus suspected of late onset growth restriction. Comparison of the UmA PI with that of the MCA may be of more value in the third trimester in determining the small fetus at risk (see below).

In the case described above there is progressive deterioration in UmA blood flow in the growth restricted twin. Because of the risks of extreme prematurity to the small baby, and its healthy co-twin, the pregnancy was carefully extended by close monitoring of the MCA and DV blood flow.

Middle cerebral artery Doppler

Assessment of blood flow and resistance in fetal middle cerebral arteries (MCA) can be useful in a number of scenarios. Although not proven to be of value, MCA Dopplers are used in both singleton and multiple pregnancies to assess growth restricted babies. In twins and higher order multiples it can be used to monitor the development of conditions such as twin-to-twin transfusion syndrome (TTTS) and twin reversed arterial perfusion syndrome (TRAP).

In order to ensure that brain oxygenation is maintained, a chronically hypoxic fetus will dilate its cerebral arteries to divert blood to the brain. This appropriate 'compensation' will be demonstrated by a falling resistance (reduced pulsatility index, PI) in the middle cerebral arteries. The PI will fall progressively as placental function, and therefore oxygen supply, deteriorates.

As described previously, increased resistance within the placental bed will be demonstrated by a rise in the UmA PI. By dividing the UmA PI by the MCA PI the cerebroplacental ratio (CPR) can be calculated. The CPR is being increasingly investigated as a tool for assessing fetal growth restriction and well-being in the third trimester, and is likely to become more widely used in the future. A meta-analysis published in 'Ultrasound in Obstetrics and Gynaecology' in 2018 concluded that whilst the CPR is useful in predicting perinatal mortality in growth restricted infants more work is needed to establish whether it can be used to improve outcomes. A low CPR indicates a fetus that is increasingly diverting blood to the brain because of increased placental resistance. A CPR <1 is associated with adverse perinatal outcomes including perinatal death, neonatal acidosis and admission to the neonatal unit. A CPR >1 gives some degree of reassurance that a small baby is not becoming hypoxic, avoiding or delaying intervention.

Measurement of the blood flow in the MCA can also be used in the assessment of fetal anaemia secondary to conditions such as Parvovirus exposure, TTTS and TRAP. An anaemic fetus will have an increased rate of flow in the MCA because of reduced blood viscosity. This will not be discussed further here as it is covered in detail in the article entitled Fetal Anaemia published in this journal in 2014.

Ductus venosus Doppler

Oxygenated blood enters the fetus through the umbilical vein. A proportion of this blood flow bypasses the liver bed through the

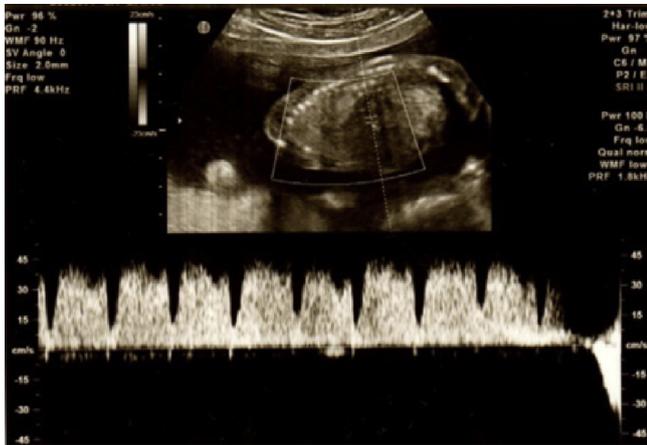


Figure 7 A normal tri-phasic DV waveform.

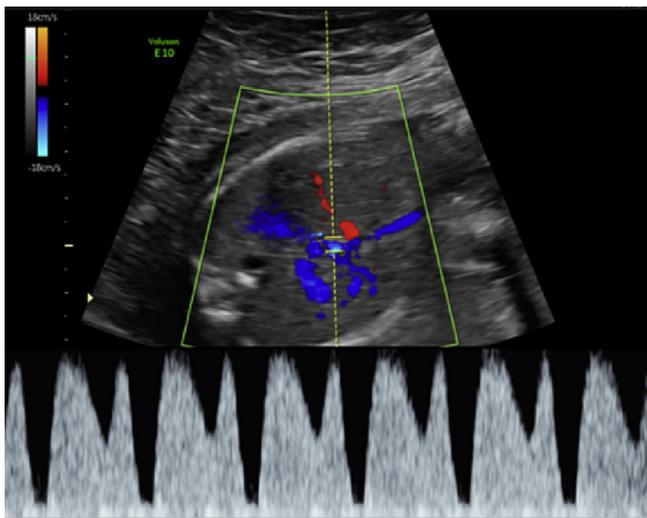


Figure 8 An abnormal DV waveform with an absent a-wave.

ductus venosus, passing directly into the inferior vena cava, on into the right atrium, then reaching the left atrium and left ventricle through the foramen ovale, ensuring that some of the most oxygenated blood reaches the brain without needing to pass through any other tissues.

The pattern of blood flow through the DV indirectly reflects fetal cardiac function. When the heart is functioning normally, blood in the DV will flow in a forward direction throughout the cardiac cycle (atrial contraction, ventricular contraction and ventricular diastole). This is demonstrated by the normal tri-phasic waveform of the DV doppler (Figure 7).

In order to compensate for low oxygen levels, the ductus venosus will dilate in the hypoxic fetus, encouraging greater flow of blood from the umbilical vein directly into the right atrium and across the foramen ovale. Resistance to flow will decrease (the pulsatility index (PIV) will fall) and the movement of blood from the placenta to the fetal heart will be maintained.

As the situation deteriorates further and the fetus becomes increasingly hypoxic and acidotic, cardiac contractility will decline. This and increased afterload caused by increased placental resistance together bring about reduced flow during atrial systole, causing first a reduction in the 'a' wave (increased

PIV), followed by absence and reversal of the 'a' wave (Figure 8). Once the a-wave in the DV is absent the fetus is likely to be acidaemic and immediate delivery should be facilitated.

The DV Doppler is used to monitor the growth restricted fetus at gestations below 32 weeks when the UmA Doppler is severely abnormal. The RCOG SFGA green-top guideline states that a DV Doppler measurement should be recorded daily if end diastolic flow in the UmA is reversed and the pregnancy has not yet reached 32 weeks' gestation. Delivery should be planned as soon as the DV 'a' wave is lost, or becomes reversed.

The TRUFFLE study aimed to clarify how to time delivery in extreme prematurity (<32 weeks' gestation). The primary outcome was survival without cerebral palsy or neurosensory disability. Delivering women too early risks more extreme prematurity, but delivering them too late risks cerebral injury from severe intrauterine hypoxia. Women were randomized into three groups: delivery when computerized cardiogram was abnormal, delivery when the DV PIV was >95th centile (early changes) and delivery when the DV a-wave was reversed or absent (late changes). Waiting for late DV a-wave changes was associated with better neurological outcomes (although there was a slight increase in perinatal mortality).

In the case described above, use of the DV Doppler allowed the pregnancy to safely continue for at least four weeks beyond the point at which the umbilical artery Doppler assessments show absent/reversed end-diastolic velocities. There is clear advantage to both babies in being born a month later than might have occurred if only an abnormal UmA Doppler assessment had been used to time the delivery. The UmA Doppler only gives information about the state of the placenta. It is the DV Doppler (and/or computerized CTG) which gives us insight into how well the fetus is coping. ◆

Practice points

- A baby born at 24 weeks' gestation has a 28% chance of surviving without significant disability. This improves to 61% at 26 weeks' gestation.
- Regular assessment of MCA and DV dopplers can help prolong a pregnancy complicated by early onset growth restriction and absent or reversed end-diastolic flow in the umbilical arteries below 32 weeks' gestation.
- Deterioration in umbilical artery Dopplers is demonstrated by a rise in PI, followed by an absence of flow, and then reversal of low, in end diastole
- Dividing the UmA PI by the MCA PI gives the cerebroplacental ratio (CPR). A CPR <1 is suggestive of fetal compromise.
- The DV Doppler is an assessment of cardiac function. Absence of blood flow through the DV during atrial contraction (absent a-wave) is a sign of significant fetal hypoxia and acidaemia, and evidence from quality trials suggest that this is the Doppler threshold for the optimum timing for the birth of a growth restricted fetus below 32 weeks' gestation.
- Assessment of UtA dopplers can help decide how frequently a high-risk women should be scanned and determine the risk of her developing pre-eclampsia or growth restriction.

FURTHER READING

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